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(54) Vehicle suspension system.

(57) A vehicle suspension system includes a vehicle body subframe (37), a wheel (11) with a tire mounted upon a wheel hub assembly having a wheel spindle (27) inside the wheel bearing (22D). A wheel damping mass (21) of ogival shape surrounds the outer face of the wheel bearing and is formed with a vertical slot (21A) whose length is perpendicular to the major diameter of the ogival cross section. The damping mass is formed with a pair of openings (47) on each side of the vertical slot that each accommodate a support assembly including a vertical shaft (45) held by a shaft retainer (44) intermediate the shaft ends, upper and lower bearings (43) and centering springs (42) located between the shaft retainer and each of the latter bearings. Damping fluid (60) may dissipate vibrational energy and may comprise a major component of the damping mass (21).

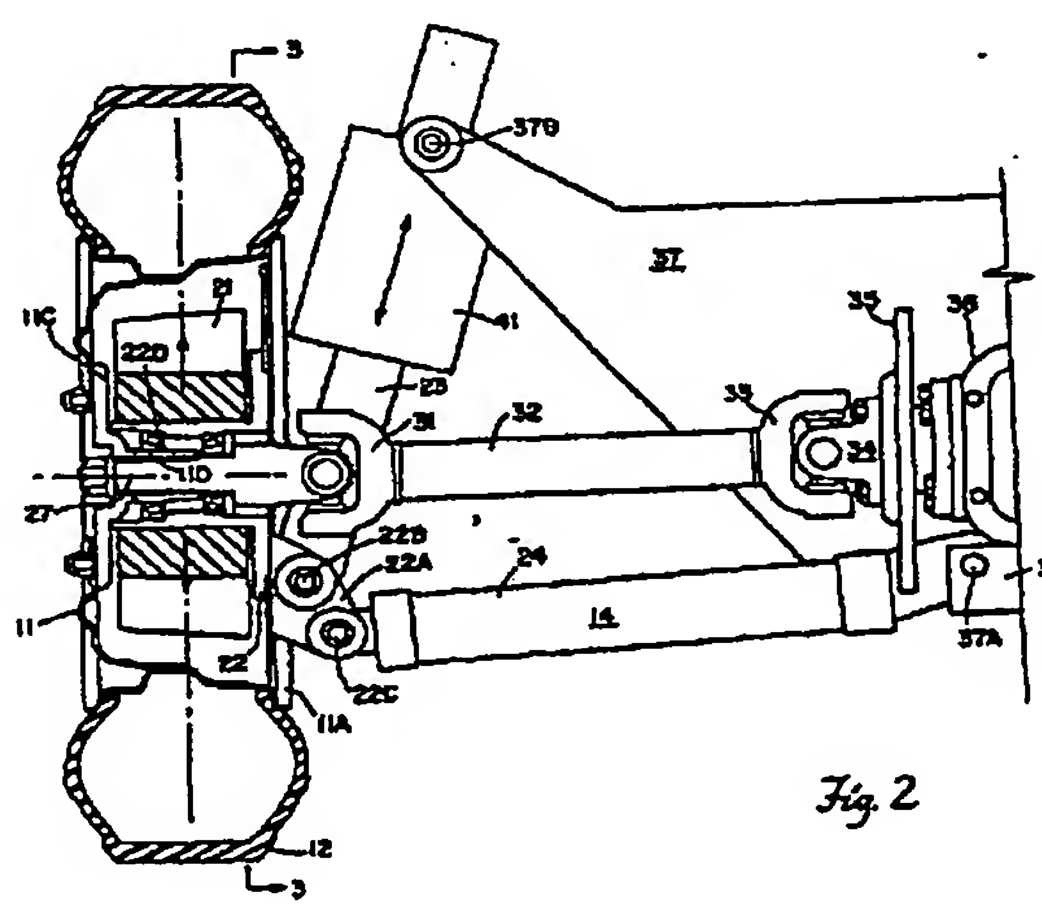

Fig. 2

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VEHICLE SUSPENSION SYSTEM

The present invention relates in general to wheel damping and more particularly concerns novel apparatus and techniques for damping a wheel substantially in its plane, such as internally of the wheel to reduce torques about the wheel center and accommodate the damping mass in a convenient location.

The use of damping masses is known. For a discussion of vehicle suspension systems with mass damping, reference is made to a paper of Ghoneim and Cheema entitled "On the Application of Optimum Damped Absorber to Vehicle Suspension," 108 Transactions of the ASME Journal of Mechanisms, Transmissions, and Automation in Design 22 (March 1986).

It is an important object of this invention to provide a vehicle suspension system with improved damping.

According to the invention, in a vehicle suspension system having a wheel carrying a tire about the rim of the wheel rotatable about the wheel axis in a rotation plane perpendicular to the wheel axis, there is damping mass means for damping vibrations located to embrace the rotation plane and disposed about the wheel axis. Preferably the damping mass means comprises an element of ogival cross section formed with a slot having its length perpendicular to the major axis of the ogival cross section and accommodating centering springs, preferably precompressed, for maintaining the damping mass means centered. Alternatively, the tire could comprise the damping mass, such as by being formed with additional distributed mass or discrete mass elements symmetrical about the wheel axis to maintain dynamic balance. Preferably, vertically mounted dashpots filled with damping fluid comprise means for dissipating vibratory energy from the wheel in the form of heat. Preferably the invention is used in a vehicle suspension system having an actuator connected between the suspended mass, such as the body subframe, and the unsuspended mass, such as the wheel.

Numerous other features, objects and advantages of the invention will become apparent from the following specification when read in connection with the accompanying drawing in which:

FIGS. 1A, 1B and 1C are diagrammatic representations of suspension systems with damping masses outside, inside and within the wheel, respectively;

FIG. 2 is a fragmentary plan view partially in section of an embodiment of the invention showing the wheel with damping mass inside relative to other components of the vehicle suspension;

FIG. 3 is an elevation sectional view through section 3-3 of FIG. 2;

FIG. 4 is a perspective view illustrating the structure of the centering springs; and

FIG. 5. is a diagrammatic elevation view partially in section of an alternative embodiment of the invention in which damping fluid also functions as a major component of the damping mass.

With reference now to the drawing and more particularly FIGS. 1A, 1B and 1C, thereof, there are shown diagrammatic representations of suspension systems having the damping mass outside, inside and within the wheel, respectively. A wheel and hub 11 carries a tire 12 and rotates about a wheel axle 13. A control arm 14 is pivotally connected to the wheel support at one end 14A, to the vehicle body, such as the differential housing, at the other end 14B and to the actuator in the middle at 14C. The actuator 15 includes actuator body 15A and a spring 15B to support the steady-state load or suspended mass 17, in this example, the vehicle body, between control arm 14 and the suspended body mass 17 of the vehicle. A damping mass 21 is shown centered about the wheel axis 13. The force F exerted on tire 12 by the ground from damping mass 21 may be divided into a component R_1 passing through the damping mass and a force R_2 passing through end 14B such that the sum of the moments of these forces about the wheel center is substantially zero. With the damping mass 21 outside the wheel as shown in FIG. 1A, both the forces R_1 and R_2 are downward. With the damping mass 21 inside the wheel as shown in FIG. 1B, the reaction force R_2 is directed upward. With mass 21 centered in the wheel according to the invention as shown in FIG. 1C, the force $F = R_1$, and there is no damping mass moment about the wheel center transmitted to body 30. Apart from omitting stresses in members caused by these moments, an advantage of the approach according to the invention is that to achieve a given effective damping, the damping mass 21 located within the wheel as shown in FIG. 1C may be less than when positioned as in FIG. 1B. Furthermore, the mechanical packaging is improved with the arrangement of FIG. 1C.

Referring to FIG. 2, there is shown a fragmentary elevation view with wheel structure in section of an embodiment of the invention with the damping mass 21 inside the wheel and hub 11. Wheel and hub 11 includes a wheel rim 11A. A stationary mass support platform 22 carries damping mass 21 and is formed with an inwardly extending arm 22A having a pivot 22B pivotally connecting platform 22

to actuator shaft 23 and a pivot 22C pivotally connecting platform arm 22 to control arm 24. Hub 11 includes a flange 11C extending from inner race 11D of wheel bearing 26 whose outer race 22D comprises mass support 22. Hub flange 11C mates with (by spline) and surrounds wheel spindle 27 connected by U joint 31 to axle 32 connected at the other end by U joint 33 to brake support member 34 that carries brake disk 35 and is connected to the differential housing drive gears 36. The other end of control arm 24 is pivotally connected at 37A to body subframe 37. Actuator body 41 is pivotally connected at 37B to body subframe 37 to actuate actuator arm 23 and counter forces exerted by the road on tire 12.

Referring to FIG. 3, there is shown an elevation sectional view through section 3-3 of FIG. 2 illustrating structural details of a preferred form of damping mass 21 and structure for supporting it. Damping mass 21 is of generally ogival shape as shown formed with a slot 21A having its length perpendicular to the long horizontal axis of the ogival cross section of damping mass 21. Damping mass 21 rests on centering springs 42 between bearings 43 and shaft retainers 44 connected to hollow shafts 45 having chambers 47 filled with damping fluid and capped by end plugs 46. Thus damping mass 21 is free to move vertically, but restrained by spindle 27 from moving horizontally. Vertical movement of damping mass 21 produces fluid displacement across damping orifice 48 to convert vibratory energy from damping mass 21 into frictional heat dissipated at orifice 48.

Referring to FIG. 4, there is shown a perspective view of the damping mass control system with edges of damping mass 27 shown in dash-dotted lines to illustrate the structure just described with caps 46 omitted.

Referring to FIG. 5, there is shown a diagrammatic plan view, partially in section, of still another form of the invention in which the damping fluid also comprises damping mass. Concentric support shaft 51 is attached to axle hub 52 by mount 53. Damper cylinder 54 is fitted over concentric shaft 51 and ride-in shaft bearings 55. Orifice plate 56 provides additional support. Springs 57 center damper cylinder 54 under static conditions. Damper cap 58 is fitted to damper cylinder 54 and sealed by welding or other suitable means.

Fill port 59 admits damping fluid 60 through back filling as air is evacuated therethrough. As wheel 61 moves up and down, damping fluid 60 is pumped from one damper chamber 62 to the other through damping orifice 62A. Shaft seals 63 prevent leakage of damping fluid 60 past shaft bearing 50. A cylinder seal 64 ensures flow of damping fluid 60 through damping orifice 62.

An advantage of this arrangement is that damping fluid 60 functions both as a viscous damping fluid and a major portion of the damping mass. Suitable fluids for use in the invention may include filled silicones, mercury or other suitable fluid, preferably with sufficient density to provide for adequate damping.

There has been described novel apparatus and techniques for wheel damping inside the wheel. It is evident that those skilled in the art may now make numerous uses and modifications of and departures from the specific apparatus and techniques herein disclosed without departing from the principles of the invention. Consequently, the invention is to be construed as embracing each and every novel feature and novel combination of features present in or possessed by the apparatus and techniques herein disclosed and limited solely by the spirit and scope of the appended claims.

Claims

1. A vehicle suspension system having a wheel axis (13), for use with an unsuspended mass comprising a wheel (11) rotatable about the wheel axis in a rotation plane perpendicular to the wheel axis and for supporting a suspended mass comprising a vehicle body, the suspension system including a damping mass means (21) for damping vibration of the wheel, characterised in that
the damping mass means (21) is located to embrace the rotation plane and is disposed about the wheel axis.

2. A suspension system according to claim 1, including a bearing (26), the damping mass means being formed with a central opening (21A) in which the bearing is located.

3. A suspension system according to claim 2, wherein the damping mass means (21) is formed with a vertical slot (21A) of a width corresponding substantially with the diameter of the bearing (26), to resist horizontal movement of the damping mass means while allowing vertical movement thereof.

4. A suspension system according to any of claims 1 to 3, wherein the damping mass means (21) if of generally ogival cross section, with the major diameter thereof substantially perpendicular to the length of the slot.

5. A suspension system according to claim 4, wherein the damping mass means (21) is formed with a vertical opening (47) on each side of the slot (21A), and further comprising
damping mass supporting means (42) for supporting the damping mass means, the damping mass supporting means having a support assembly (42-46) seated in each of the openings (47), each of the support assemblies including,
a vertical shaft (45),

a shaft retainer (44) intermediate the ends of the shaft, supporting the shaft;
upper and lower bearings (43), and
centering springs (42) between the shaft retainer and each of the bearings.

6. A suspension system according to claim 5, wherein the centering springs (42) are precompressed.

7. A suspension system according to any of claims 1 to 6, further comprising
an axle (32) connected to a wheel spindle (27),
a control arm (14) pivotally connected between the damping mass support means and the vehicle body (37) in use, and
actuating means (41) for resisting vertical movement of the wheel, pivotally connected between the vehicle body and the damping mass support means in use.

8. A suspension system according to claim 1, further comprising energy storage means (57) connected to the damping mass means (21) for exchanging energy therewith, and energy dissipating means (54) connected to the damper mass means (21) for dissipating vibrational energy.

9. A suspension system according to claim 8, wherein the energy staorage means comprises a spring (57) and the energy dissipating means comprises a dashpot (54).

10. A suspension system according to claim 8 or claim 9, wherein the energy dissipating means comprises damping fluid (60) which also comprises a major component of the damping mass means.

11. A suspension system according to claim 5, wherein the support assemblies each further comprise end chambers (62) carrying damping fluid (60), the respective vertical shaft (51) being seated in the end chambers and displacing damping fluid when the damping mass means is in motion.

12. A suspension system according to claim 11, wherein the vertical shaft is hollow and comprises the damping mass support means, and wherein the support assembly further comprises means (62A) for allowing the passage of of damping fluid from a first of the chambers to a second.

13. A suspension system according to claim 12, wherein the means for allowing passage of damping fluid comprises a restrictive orifice (62A) for establishing a predetermined damping factor.

14. A suspension system according to claim 12 or claim 13, further comprising shaft bearings (55) defining cylinders for the hollow vertical shafts, to act as pistons.

15. A suspension system according to claim 14, comprising a concentric assembly of a damper cylinder (54) accomodating damping fluid (60), a spring (57) forming the energy storing means, an orifice plate (56) defining the orifice (62A), and a support shaft (51).

16. A vehicle having a suspension system according to any of claims 1 to 15.

17. A vehicle according to claim 16, further including a wheel (11), the wheel having an annular region around the wheel axis (13), the damping mass means (21) being located in the annular region.

18. A vehicle according to claim 17, when dependent on claim 7, wherein the energy storage means and the energy dissipating means are located in the annular region.

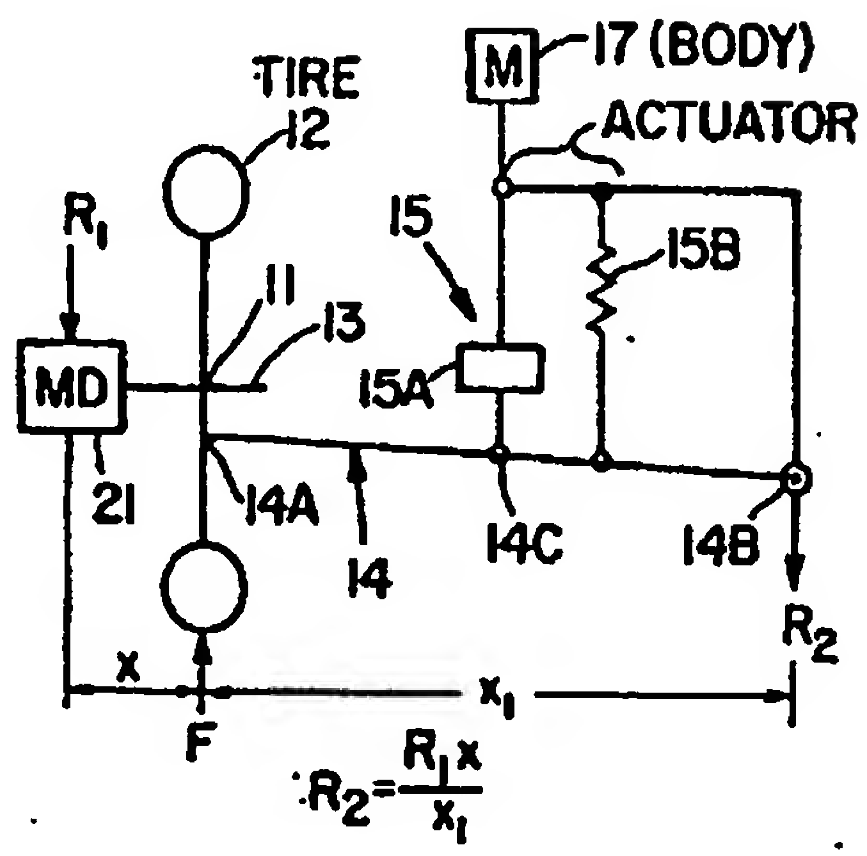

Fig. 1A

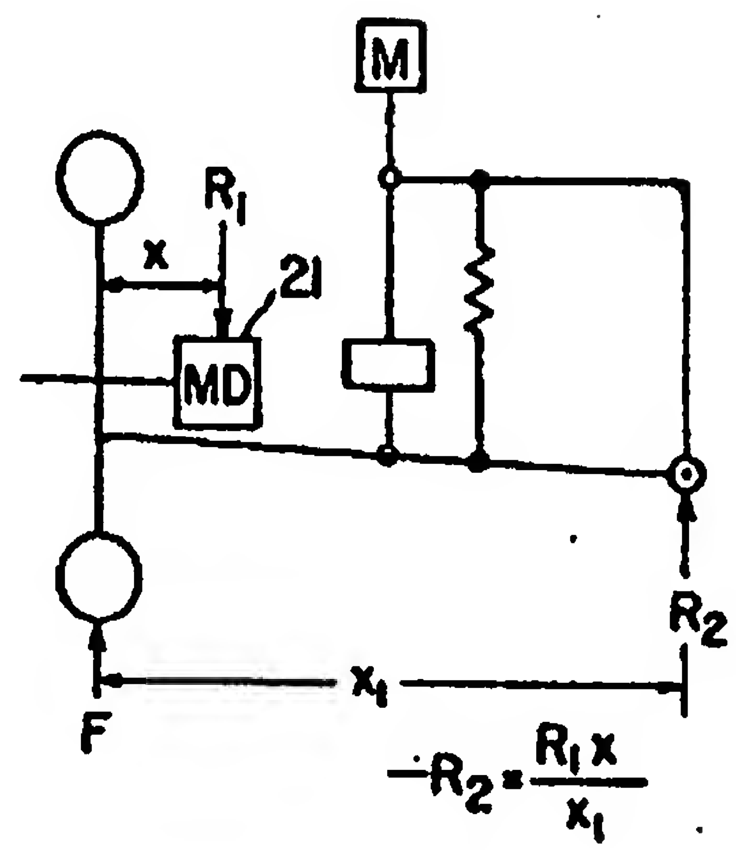

Fig. 1B

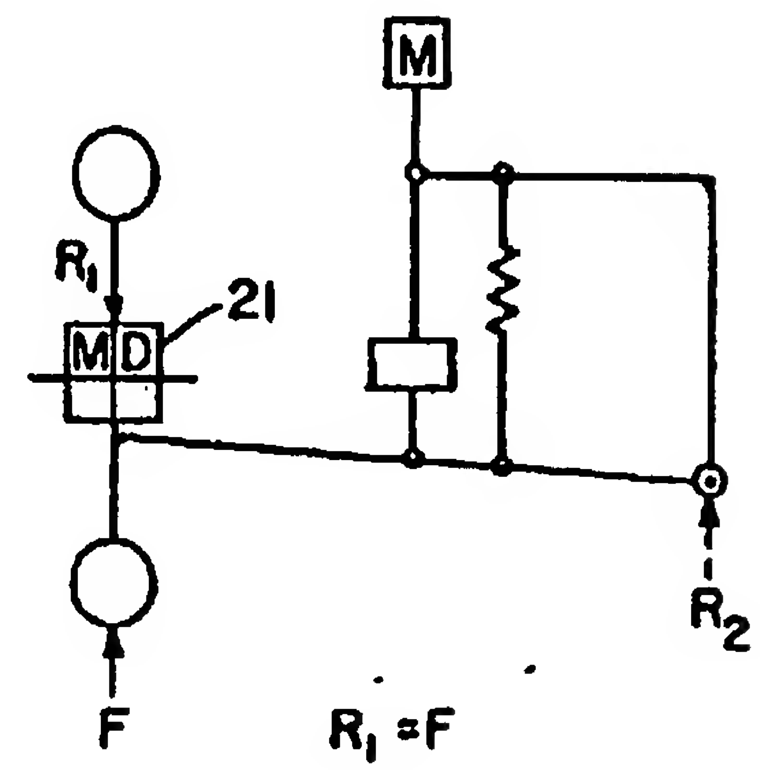

Fig. 1C

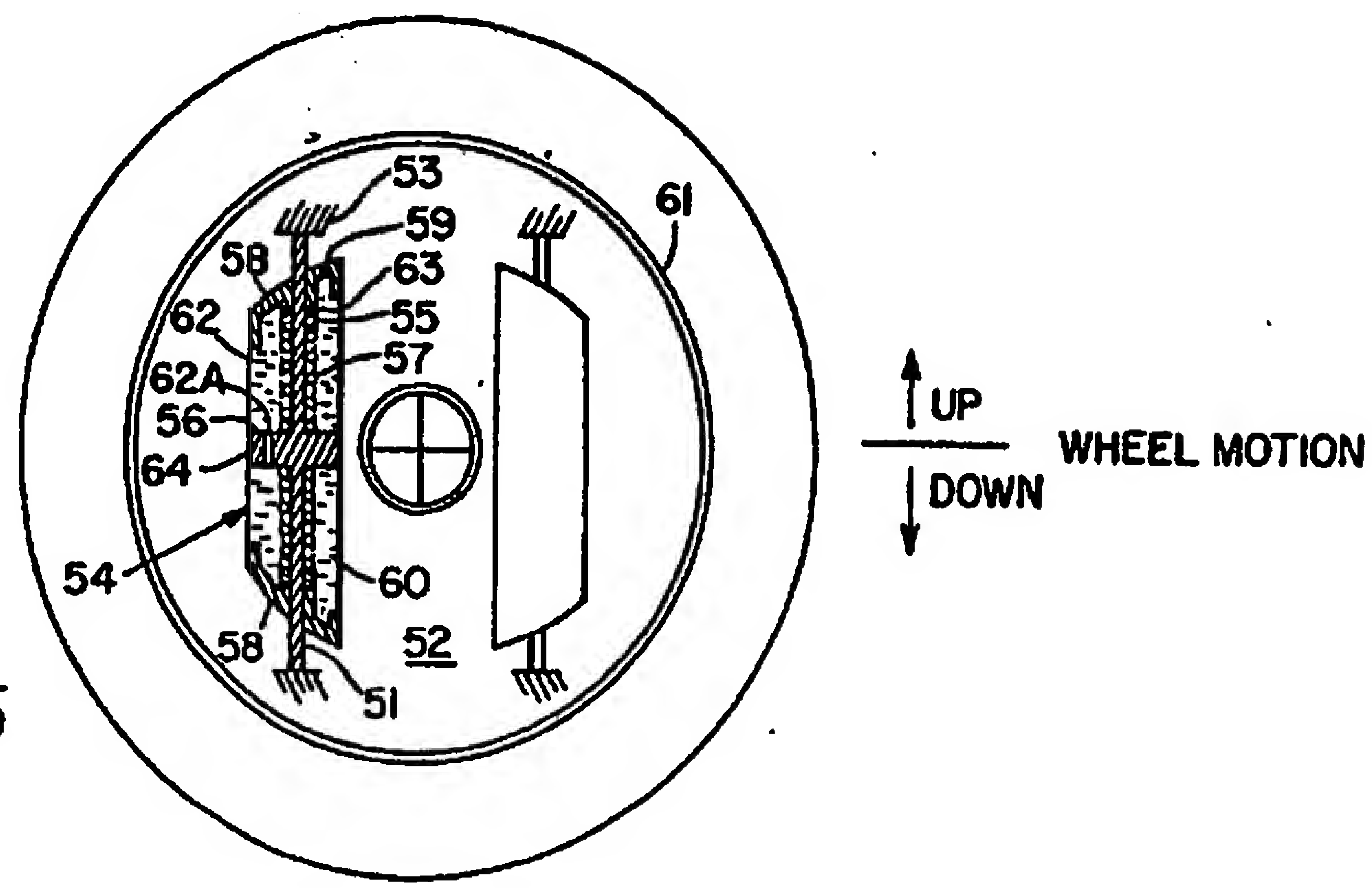

Fig. 5

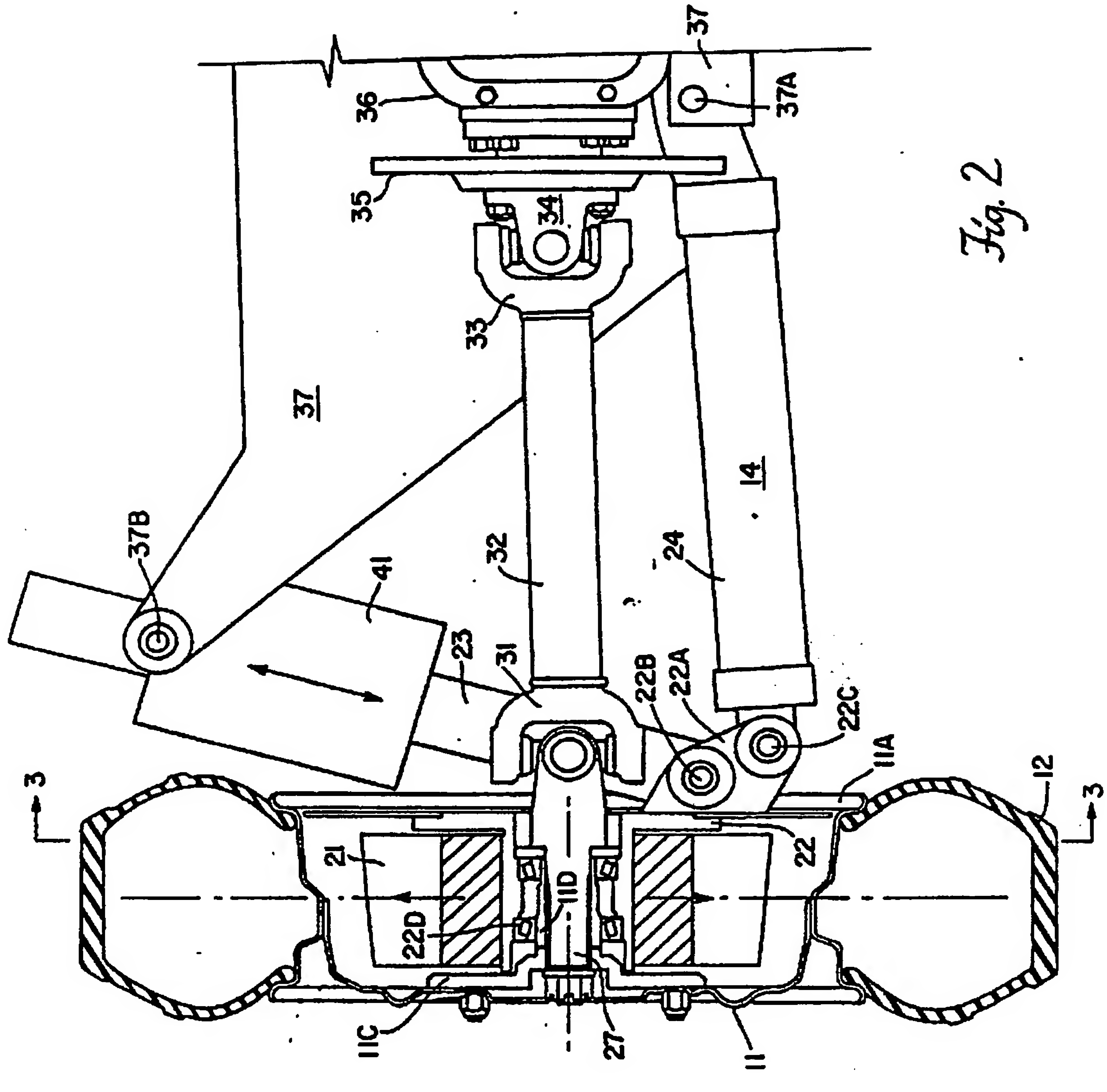
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Fig. 2

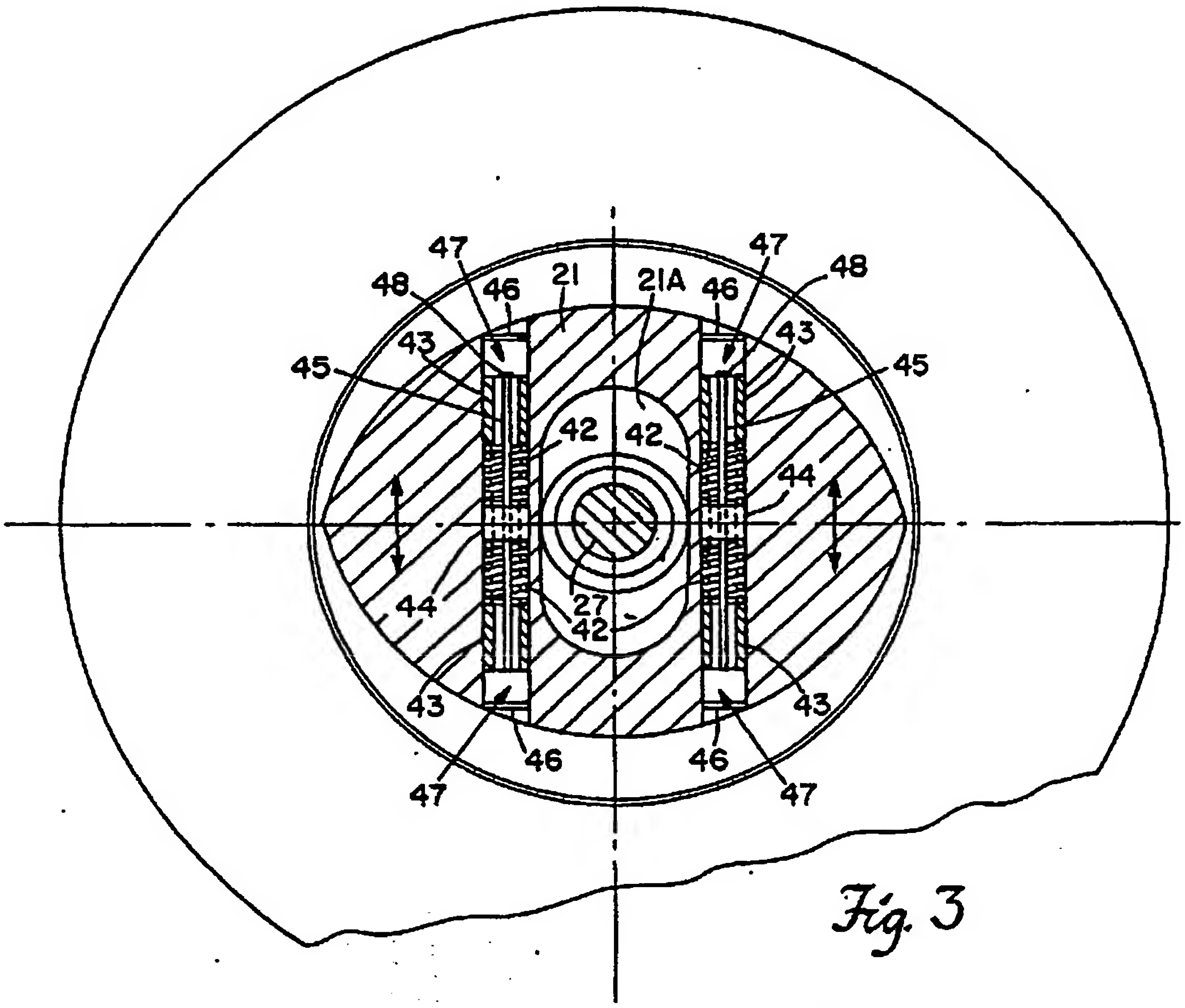
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Fig. 3

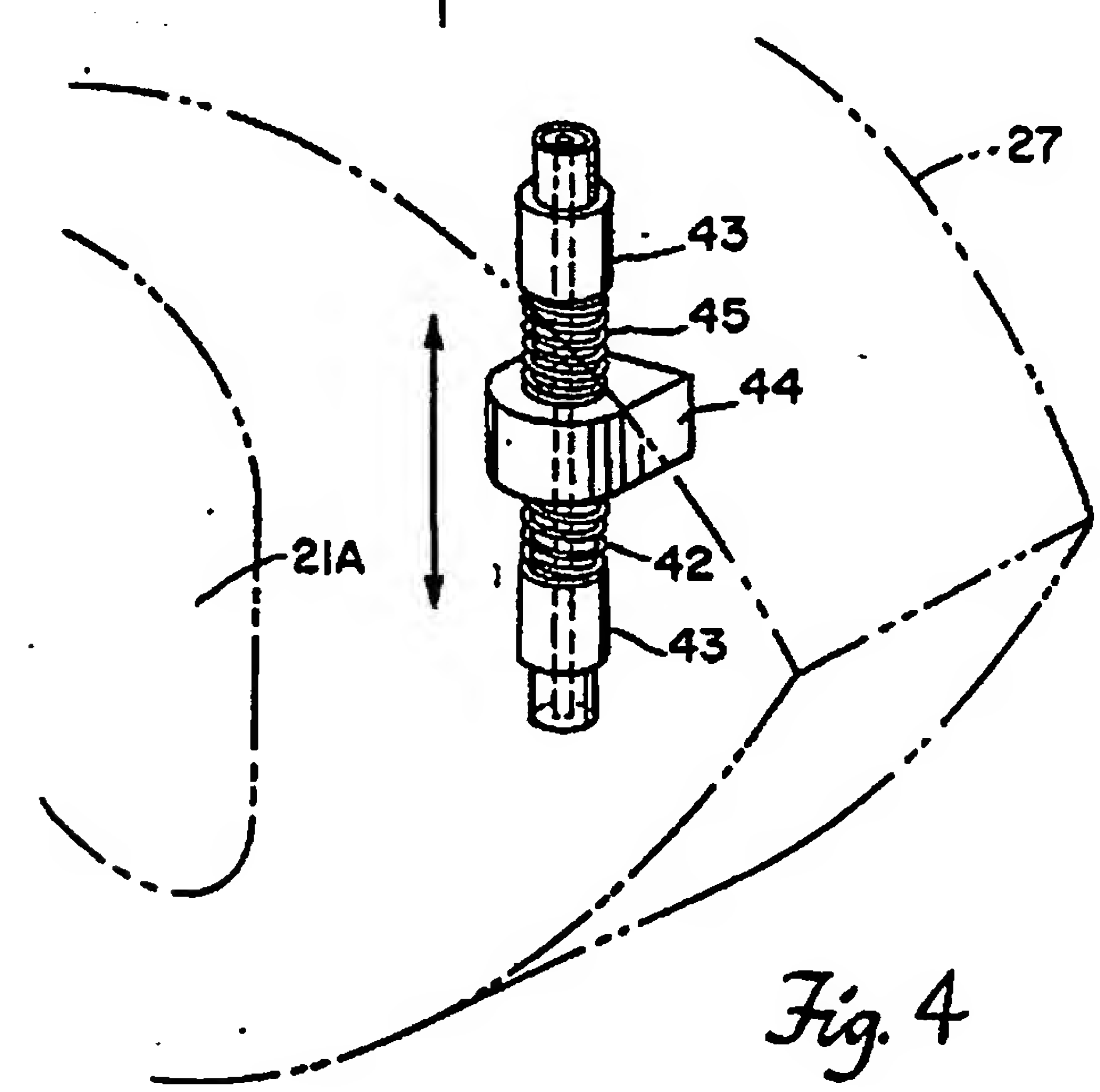
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Fig. 4

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EUROPEAN SEARCH REPORT

Application Number

EP 89 30 4550

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	US-A-2 955 841 (K.E. FAIVER et al.) * Column 1, lines 51-56,63-66; claims 12-13; figures 1-2 *	1,2	B 60 G 13/18 F 16 F 7/10
A	US-A-2 537 479 (MOTTE) * Figures 5-6 *	3	
A	US-A-2 901 239 (P.R. SETHNA) * Figures 1-2 *		
A	FR-A-1 409 520 (DAIMLER BENZ AG)		

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

B 60 G 13/00
B 60 B 9/00
B 60 G 15/00
F 16 F 7/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	14-09-1989	BOLJANAC T.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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